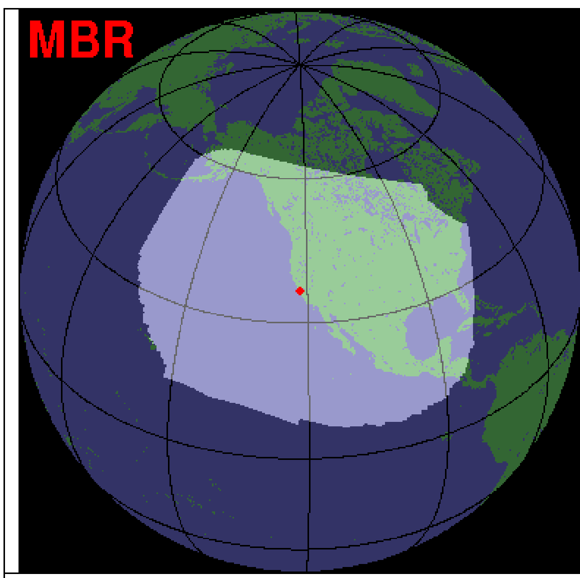
Appendix 4 Direct Downlink Ground Stations and Relay Satellites

A Ground Stations - SEAWIFS

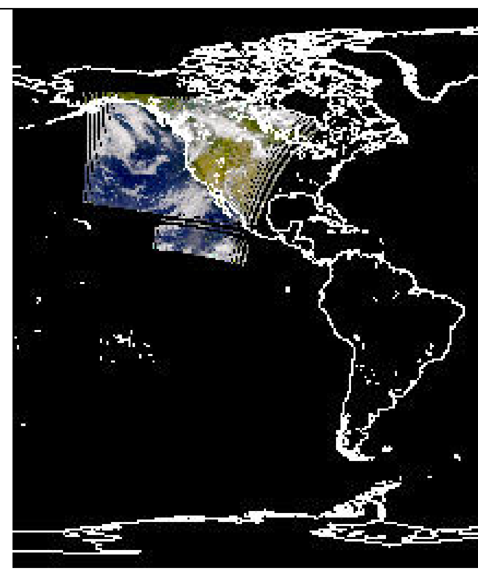
The SEAWIFS satellite is a remote sensing system designed to monitor the earth's oceans on a daily basis. The single instrument payload has an 8-band sensor covering the 400-885 nanometer wavelength range from a sun-synchronous orbit at 705 km altitude. The sensor has 1.1-km resolution, and covers a 2800 km swath (58°). The data are digitized at 10 bits resolution.

Two telemetry streams are transmitted. The first is real-time data, termed LAC, at 1 km resolution. LAC data are merged with spacecraft health and instrument telemetry and transmitted at 665.4 kbps at L-band (1702.56 MHz). The other telemetry stream consists of stored data which has been resampled to 4.5 km resolution, termed GAC. These data, with selected LAC, are transmitted along with spacecraft health and instrument telemetry, at 2.0 Mbps at S-band (2272.5 MHz) twice a day to the ground site at NASA/GSFC. The command system uses S-band with an uplink of 19.2 kbaud at 2092.59 MHz.
http://seawifs.gsfc.nasa.gov/SEAWIFS/SEASTAR/SPACECRAFT.html

Real time data are downlinked to 127 authorized ground stations around the world.
(http://seawifs.gsfc.nasa.gov/cgi/hrpt_station_info.pl)



Moss Landing Receiving Station for SEAWIFS – Field of Coverage



August 4, 2002 Collected data for the Moss Landing Station

A local station which covers the west coast and our quarter or so of the Pacific Ocean is at Moss Landing, just north of Monterey. The two figures shown here illustrate the area for which that ground station receives data.

B Relay Satellites - TDRSS

In the early phases of the space age, NASA and the AF maintained a large array of ground stations to communicate with their satellites. The ground stations were expensive, and did not provide continuous coverage, particularly for the low-earth-orbiting satellites. NASA developed the idea for a global system of communication satellites which culminated with the launch of TDRS-1 on April 4, 1983. Following the loss of TDRS-2 in the Challenger accident in 1986, five (5) more TDRS satellites were launched over the next nine (9) years. The original TRW built satellites are now being supplemented (replaced) by Boeing built satellites, beginning with TDRS-H. TDRS-H (now known as TDRS-8), the first of the replenishment spacecraft, was launched on June 20, 2000. TDRS-I was launched March 8, 2002, and TDRS-J is scheduled to be launched November 20, 2002. I'll be 50 on that day.

Nominal stations are at 120 E (TDRS 3), 90 W (5, 7, G, H), and 120 W (1, 4, 6) ????. based on STK simulation. GSFC notes suggest H is supposed to be at 171 W ?
TDRS-East, 41 W; TDRS-West, 174 W;
Interesting note – TDRS-1 has drifted far enough in its orbital inclination that it can serve as a relay for ground station at the south pole. 1/12/1998 -
http://msp.gsfc.nasa.gov/SPTR/sptrfaq.txt

The complete system, known as the Tracking and Data Relay Satellite System or TDRSS, consists of the satellites, two ground terminals at the White Sands Complex, a ground terminal extension on the island of Guam, and customer and data handling facilities. This constellation of satellites provides global communication and data relay services for the Space Shuttle, International Space Station, Hubble Space Telescope and a multitude of low earth orbiting satellites, balloons and research aircraft.

Ref: http://tdrs.gsfc.nasa.gov/tdrsproject/about.htm

1 White Sands

The White Sands Complex (WSC) is located near Las Cruces, New Mexico and includes two functionally identical satellite ground terminals. These terminals, known as the White Sands Ground Terminal (WSGT) and the Second TDRSS Ground Terminal (STGT). The ground stations include three (3) 18.3 meter Ku-band antennas, three (3) 19 meter Ku-band antennas and two (2) 10 meter S-band TT&C antennas.
http://nmsp.gsfc.nasa.gov/tdrss/wsc.html; http://www.spacedata-int.com/pages/white.html

White Sands Ground Terminal

Second TDRSS Ground Terminal

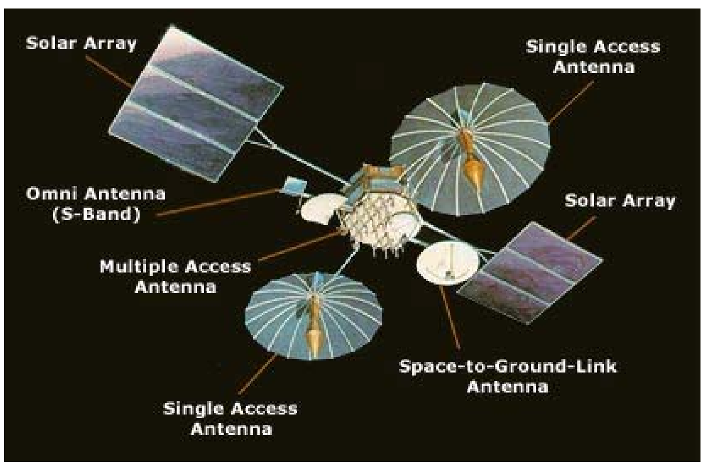
2 TDRS 1 to 7

a Satellites

The Tracking and Data Relay Satellite series began with a TRW built vehicle illustrated in the image below. The Solar Array consists of six panels configured into two boom-mounted wings of three 3.84-meter square panels. The weight of the array is approximately 288 pounds and the total area of the array is ~29 m^2. The wings are rotated about a common axis by two identical solar array drive assemblies and are individually sun oriented by the Attitude Control System. The total power output of the solar array is approximately 1800 watts.

There are two 40 Ampere-Hour nickel-cadmium battery assemblies, providing 1.4 KW power during eclipse intervals.

A hydrazine propulsion system with 24 4.45 N thrusters is used for orbit circularization and orbit maintenance. Spacecraft telemetry and commanding are performed via a Ku-band communications system, with emergency backup provided by an S-band system.
http://tdrs.gsfc.nasa.gov/tdrsproject/tdrs1.htm#1



TDRS 1-7 Spacecraft; Dimensions: 45 feet wide; 57 feet long; Weight 5000 lbs; Power (EOL) 1800 watts

b Payload (http://msl.jpl.nasa.gov/QuickLooks/tdrssQL.html)

Antennas :

Two Single Access (SA) antennas - each antenna is a 4.9 m diameter molybdenum wire mesh antenna that can be used for Ku-band and S-band links. Each antenna is steerable in 2-axes and communicates with one target spacecraft at a time.

One Multiple Access (MA) S-band antenna array - an electronically steerable phased array consisting of 30 fixed helix antennas. The MA array can receive data from up to 20 user satellites simultaneously, with one electronically steerable forward service (transmit) at a time. Twelve of the helices can transmit and receive, with the remainder only able to receive. Relatively low data rates are supported – 100 bps to 50 kbps. NASA Press Release, TRACKING AND DATA RELAY SATELLITE SYSTEM (TDRSS) OVERVIEW; Release No. 91-41; June 7, 1991

One Space to Ground Link antenna (SGL) - a 2-meter parabolic antenna operating at Ku-band that provides the communications link between the satellite and the ground. All customer data is sent through this dish, as are all regular TDRS command and telemetry signals. The antenna is gimballed on two axes.

One S-band omni antenna - a conical log spiral antenna used during the satellite's deployment phase and as a backup the event of a spacecraft emergency. This antenna does not support customer links.

One small Ku-band and one small C-band antenna are also carried, designed to support communications with Westar satellites, but are no longer used.

Transponders
Four (plus 2 spare) 25W Ku-band TWTAs for LP (linearly polarized) zone coverage
Two (plus 2 spare) 1.5W Ku-band TWTAs for CP (circularly polarized) spot coverage
Two (plus 4 spare) 25W Ku-band TWTAs for LP zone coverage
Two (plus 2 spare) 1.5W Ku-band TWTAs for CP spot coverage
12 5W TWTAs for LP C-Band up/down
Two (plus 2 spare) 26W S-band SSPAs (used for intersatellite links)
Eight (plus 4 spare) 3.5W S-band SSPAs (used for intersatellite links)

3 TDRS H

The TDRS H, I, J spacecraft are based on the body-stabilized Boeing (Hughes) 601 satellite.

The propulsion and reaction control system is a bi-propellant system using monomethyl hydrazine fuel and nitrogen tetroxide oxidizer. The system uses a 110 pound force liquid apogee motor for orbit insertion and four 2 pound force thrusters and eight 5 pound force thrusters for on-orbit operations and attitude control during orbit insertion.

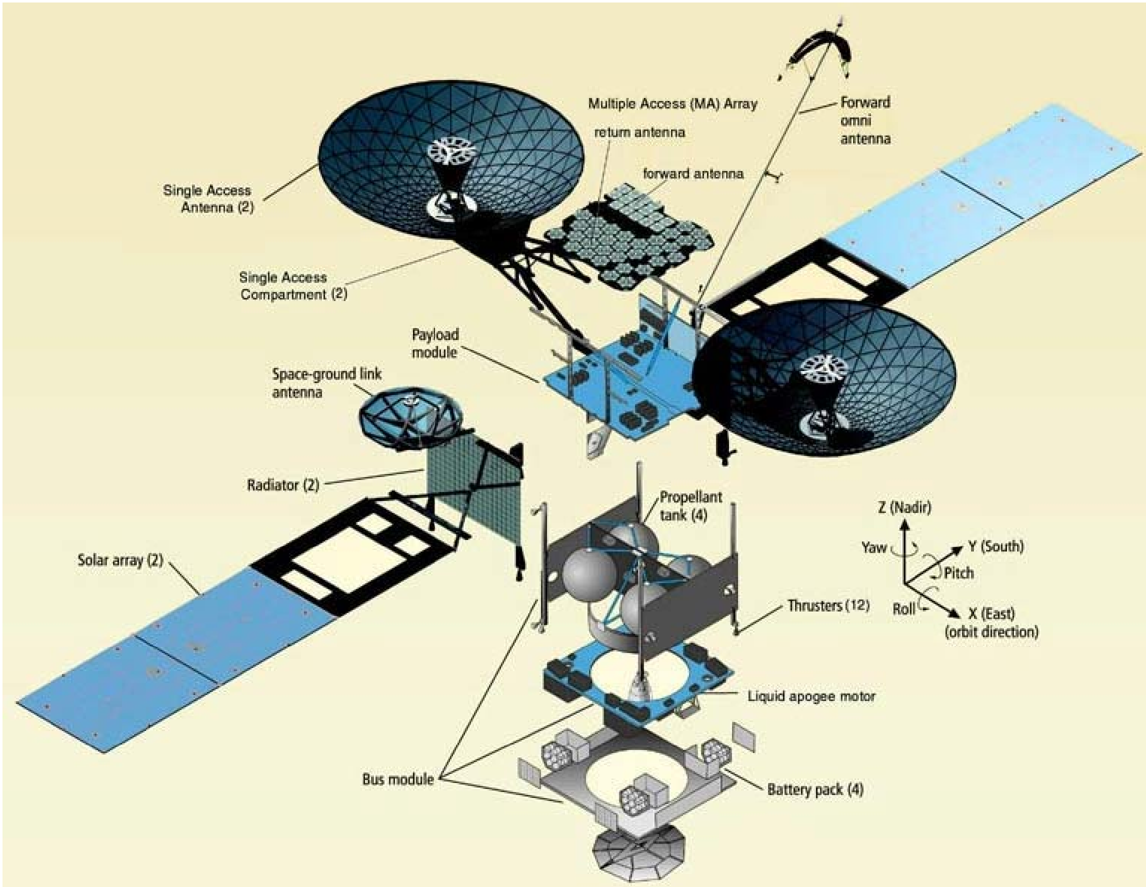
The attitude control system is a momentum bias design, using a gimbaled momentum wheel for active three-axis torquing and momentum storage. Continuously operating gyros, updated by earth and sun sensors, provide accurate three axis attitude sensing and are used both to maintain an earth pointed spacecraft attitude and to provide antenna pointing control compensation.

The attitude control subsystem has an on-board processor, providing some measure of autonomy over the existing fleet. It also provides tighter pointing capability, which is required for the narrow bandwidth, used for the Ka-band service. Additional features include fault protection and the use of a hemispherical resonating gyro rather than one of mechanical design with moving parts that can wear out.

A system of heat pipes, multi-layer insulation, radiators and thermostatic heater control, provide autonomous thermal control for all deployed operations.

Two wings covered with silicon solar cells provide a 15-year end of life power of approximately 2300 watts. Nickel hydrogen batteries, which supply power during eclipses, have autonomous battery charge maintenance. They do not require the seasonal reconditioning of the commonly used nickel cadmium batteries.

Dimensions	21 meters long (68 ft. 10 in.) with solar wings deployed. 13 meters wide (43 ft. 5 in.) with antennas deployed
Weight	At liftoff, 3180 kg (7,011 lbs). Weight includes 1671 kg of expendable fuel.
Lifetime	11 years operational plus up to 4 years of on-orbit storage
Power (EOL)	2042 watts
Mass (dry)	2909 (nominal); 3287 (allowable)
Fuel (liftoff)	3675 lbs; 308 lbs (GEO)
Services	Ka, Ku & S-Band telecommunication services
Launch Vehicle	Atlas II-A



SINGLE ACCESS (SA) ANTENNA (2)
These two (2) large (15 foot diameter) very light antennas are pointed at individual user satellites to transmit and receive data using one or two radio frequency (RF) channels (S-band and either Ku-band or Ka-band).

MULTIPLE ACCESS (MA) ARRAY
The array consists of two antennas; one each for transmitting to and receiving from users. The phased array antenna can form two (2) beams for transmitting to users, and up to six (6) beams that can receive from users simultaneously.

SPACE-GROUND-LINK ANTENNA (Ku band)
This smaller (2-meter diameter) antenna always points at the TDRS ground station at White Sands, New Mexico.

a TDRS H, I, J Payload Characteristics

The TDRS H, I, J provides 18 service interfaces to user spacecraft. The onboard communications payload can be characterized as bent-pipe repeaters, in that no baseband processing is done by the TDRS.

S-Band Multiple Access

The *phased array antennas* are designed to receive signals from five spacecraft at once, while transmitting to one, providing simultaneous service to satellites that generate time-critical data. Improvements in the multiple access gain to noise temperature ratio and on-board processing have contributed to increasing the data rate to thirty times over that of the existing fleet. The forward service transmitting power is increased by 8 dB. These improvements permit the offloading of many satellite users from the current fleet's busy S Band Single Access antennas to the TDRS H, I, J MA system.

S-Band Single Access

Two 15-foot diameter mechanically steerable antennas offer a range of frequencies providing high gain support to satellites with low gain antennas or MA users temporarily requiring and increased data rate. They are used to support manned missions, science data missions including Hubble Space Telescope, and satellite data dumps.

Ku-Band Single Access

The two 15 foot antennas also operate at a higher bandwidth supporting high-resolution digital television including all space shuttle video communications. Recorders aboard NASA satellites can dump large volumes of data at rates of up to 300 million bits per second (300 MB/s). That's equivalent to a 20-volume encyclopedia or about 6 million words every second.

Ka-Band Single Access

A new tunable, wideband, high frequency service offered by the 15-foot antennas provides for the capability of data rates up to 800 million bits per second. This Ka-Band frequency also establishes interoperability with international community such as the Europeans and Japanese

Baseline Service	Service		TDRS 1-7	TDRS H,I,J	Notes
Single Access (SA)	S-Band	Forward	300 kbps	300 kbps	No change
		Return	6 Mbps	6 Mbps	
	Ku-Band	Forward	25 Mbps	25 Mbps	No change
		Return	300 Mbps	300 Mbps	
	Ka-Band	Forward	N/A	25 Mbps	22.55-23.55 GHz frequency band
		Return	N/A	800 Mbps	25.25-27.50 GHz frequency band
	Number of links per spacecraft		2 SSA 2 KuSA	2 SSA 2 KuSA 2 KaSA	For TDRS H, I, J simultaneous operation of S & Ku and S & Ka services, a single SA antenna is required.
Number of Multiple Access Links per Spacecraft (MA)	Forward		1 @ 10 kbps	1 @ 300 kbps	Anticipated SSA users less than 3 Mbps offloaded to TDRS H, I, J MA
	Return		5 @ 100 kbps	5 @ 3 Mbps	
Customer Tracking			150 meters 3 sigma	150 meters 3 sigma	No change

http://tdrs.gsfc.nasa.gov/tdrsproject/spacecraft.htm#5